Department of Computer Science

Technical Report

AgentcitiesUK.net Challenge Day 1: e-Health

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Technical Report CSBU-2005-08 **October 2005**

ISSN 1740-9497

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ISSN 1740-9497

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1 Introduction

The first Challenge Day (CD1) of the AgentcitiesUK network took place in Bath on 22-23 September 2004 and addressed the use of intelligent agents in health care.

The meeting began with a round table of introductions and the project coordinator (Julian Padget) outlined a schedule for the two days and a proposal for the working method of the group. Several participants had submitted sketches of scenarios involving the use of intelligent agents in novel applications in support of healthcare (see `http://agentcitiesuk.net/cocoon/java/events/cd1-topics.section`), and the meeting proper began with the presentation of these ideas in order to stimulate debate and set the scene for later discussion.

Following lunch the participants discussed how work might be divided up (clustering similar proposals, random allocation, identification of themes etc.) and concluded by setting up three groups, one each for acute (covering A&E from small accidents to major incidents), chronic (mental health, the elderly, back pain, drug addiction) and clinical (surgical, diagnostic and nursing support) settings. The report back session at the end of the afternoon showed that all groups has largely spent their time establishing the limits of their investigations, and attempting to agree on definitions of critical terms, as well as exploring a range of scenarios. This process continued over dinner and through the evening until late.

The groups continued discussion the next morning, but in contrast to the previous day, were now trying to pull together the ideas from the earlier exploration to present a prototypical problem, the issues arising from this and outline solutions where agents might enable a qualitative improvement by supporting human activities. Each group produced a short report addressing these issues and each report (edited for consistency of presentation) appears below.

The aim of the two-day workshop was to explore the application of agents in radically new contexts where the particular properties of agents could be advantageous. Following the opening discussion, the participants decided to divide into three groups to focus on healthcare support in three distinct areas:

1. **Acute** where the need is for rapid collection and dissemination of information and coordination of resources.
2. **Clinical** where the need is for continuity and relevance of information, but in an information rich and high-tech environment.
3. **Chronic**, where there is a similar need for continuity of information, but typically this information may be distributed across multiple agencies and the environment is relatively low-tech.

Group Rapporteurs: Tim Norman, Chris Reed, Simon Thompson, Leon Watts
Editor: Julian Padget

2 Acute scenario

The key issues identified in the acute scenario were access, management and control of information relevant to a healthcare incident, in particular the need to enable the transfer of information from one person to another: for example, from paramedic to A&E doctor. Scenarios included:

- Large scale accidents, such as a train wreck or a terrorist attack and
- Small scale events, such as a car accident or someone collapsing.

From a human/user perspective, it was agreed that such a system needed to be "handy" but utilisation ought not be compulsory and that information needed to be focused in that there should be little or no superfluous information.

Identified potential benefits included:

- Linking of patient records and incident
- Dissemination and collation of information
- Support for operators/dispatchers combined with reduced cognitive load and that could benefit decision-making
- Automation of content management and the task of distributing information
- Enabling various forms of informal reporting / blogging / e-post-its and "Out of process" support
- Encouraging community building

A sketch of this idea appears in Figure 1.

3 Why Agents?

A necessary question to address is what might make an agent solution so much better than a conventional software solution. What advantages and benefits make this problem suitable for an agent approach? The following attributes were put forward:

- The modular architecture intrinsic to agents would help with maintenance and extensibility, especially as new technology becomes available.
- The loose coupling of agent-based software makes the it possible to leverage and support existing systems at the same time as deploying new components.
- Agents do not impose any additional burden on users, but offer the opportunity for new approaches to the presentation information, including, representation of rôles and the personalisation of the system by rôle, so that different services and different responses may be made available to different actors

A range of other generic "business" aspects were highlighted:

- The potential for more effective and more efficient work by individuals through the timely delivery of personalized information.
- Opportunities for serendipitous cross-fertilization through agent connectivity
- Increased chances of recovery and reduction in the seriousness of consequences if injury through improved insight (reduced cognitive overhead identified earlier) and the sharing of expertise.
- The possibility for enhanced community learning through more complete records and the opportunity to re-run scenarios.
- Improved retention of information and control of access to information.

A brief consideration was given to how such an acute support system might be implemented, for which the following steps were identified:

1. The initial system should be as simple as possible
2. Intelligence and value-adding components should be developed and bolted on as required.
3. Trialling should take place in small scale settings, where subsequent evaluation would be feasible, such as clinics and GP practices.

Prototypical scenarios are:

Major accident: helping teams co-ordinate and share information; rapidly disseminating information

Walk in clinics: providing support and community to isolated practitioners

Teams: Supporting shift working/flexi-working/supply and casual working in teams, where there is

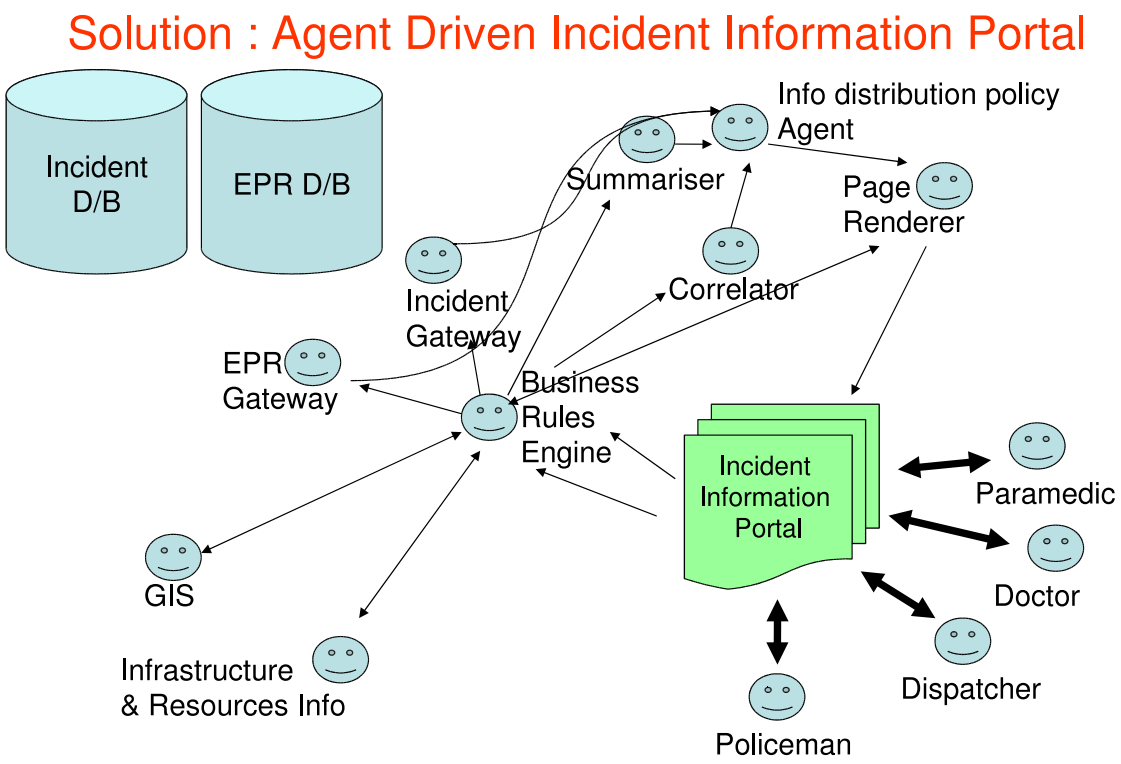

Figure 1: Agent Driven Incident Information Portal

a strong requirement for continuity of care, but for the same reason there is not continuity of personnel

4 Clinical scenario

This group was assigned the task of focusing on the application of autonomous agents and multi-agent systems models and techniques to the support of the management of clinical care in the NHS and health sector in general. The remit was to highlight common problems in this aspect of health care that may benefit from such computational solutions, and to identify specific requirements and strategies for their deployment.

Discussion was motivated generally by the experiences and expertise of those in the team with experience in clinical care, and specifically by three scenarios:

(i) supporting the process of identifying the most appropriate recipient of donor organs and bringing together organ, recipient, and transplantation team in a timely manner;

(ii) supporting the coordination of multi-agency teams in the delivery of health services and the automated generation of activity logs for purposes of CPD monitoring and audit; and

(iii) supporting clinical research through the use of distributed data-mining of anonymised patient information.

Although there are many similarities between these activities in terms of the requirements of computational support systems, there are a number of key distinctions that were identified. For instance, although most clinical scenarios require decisions to be made in a timely manner, scenario (i) represents a class of problems in which hard deadlines must be met. In the organ donor scenario, a solution that does not meet a specific deadline is not a solution to the problem. This means that solutions have to be produced in a timely manner, and the nature of the solution should be such that it is feasibly enacted in the time available. Issues that are common to all three scenarios include the need to ensure that clinical staff at all levels and in all areas of expertise are closely involved at all stages in the development and deployment processes, and to introduce new, supporting functionality gradually into the community to avoid information technology overload.

4.1 Organ Transplantation

There are many problems evident in present procedures for identifying the most appropriate recipient of a donor organ. The first issue to note is that information about available organs and possible recipients is faxed between hospitals and organ transplant coordinators. The infrastructure necessary for the electronic transmission of this information is not yet in place, and this would be a barrier to the development and deployment of automated support of this process. Given that the gradual introduction of new processes and support systems is a key element to successful utilisation of agent-based solutions, some progress is required before it would be practical to introduce agent-based technologies. On the other hand, some work has been done in this application area in the European Economic Areas, and hence there is research to build upon.

Having said all this, the exercise of identifying requirements for such a system was considered to be a worthwhile exercise for the group. The key requirements identified were:

1. The task is inherently time critical, which is a characteristic of many problems in healthcare. Such domains are classed as real-time, which means that there exist deadlines beyond which no solution, however good, has any utility. Furthermore, it is often the case that such deadlines are uncertain.

2. The ideal support for this task identified by the group was for agents to be used to coordinate the flow of up-to-date information to the coordinator about availability of organs for transplantation and their characteristics (including geographical location), the availability of transportation and other necessary resources, and information concerning patients in need of transplants. Here, the system facilitates and supports the clinical decisions made by existing experts.

3. The possibility of employing a market-based solution to automate the decision of which patient should receive the organ was discussed. This was generally considered not to be a reasonable option for a number of reasons. First, it is difficult (if not impossible) to reduce the various issues/influences on a decision to some utility value or cost for the submission of a bid in some

kind of auction. Secondly it is neither desirable nor possible to replace the expert decision maker with an AI system.

4. Although a market-based mechanism was considered undesirable, mechanisms that automatically provide the clinical decision maker with a set of options that comply with a set of general constraints may very well provide useful. The prerequisite for this would be for each party to provide details of their constraints in a machine-readable form.

4.2 Supporting multi-agency teams

- Cross-agency planning.
- Process descriptions in different agencies, but no coordination between them, and certainly no assessment of the interdependencies between them. Until you can get a high level plan that picks up dependencies to facilitate communication and coordination, you're not going to get any benefit. The plans should not and need not be down to the finest detail, but more abstract, and you want a "tool box" model (similar to that used in the Oil Industry) where you have plan B and plan C, etc. The Business Continuity Institute do something like this: `http://www.thebci.org`.
- Scheduling activities of clinical staff to manage resources more effectively. A centralised scheduler may produce optimised schedules, which do not necessarily take into account unstated constraints on individual activities.
- Any proposal must be robust to failure and back-up systems need to be in place.
- Systems should reflect how they operate at present and gradually, incrementally introduce function, with frequent feedback from users — a user-centred approach.
- Electronic Patient Records (EPRs) are becoming more prevalent, but so also are Staff Records that capture the roles and responsibilities of that member of staff. These staff records are principally used for staff training and CPD (NHS University). The failure of the current system is that the HR Departments wish to compartmentalise staff, and do not capture any notion of their experience.
- In monitoring processes, you can extract information about what has been done and by whom and hence determine the experience of the member of staff. At present, the member of staff is required to complete logs (Edinburgh College of Surgeons do this).
- Issue of roles and their relation to clinical procedure. Modelling the roles involved in a procedure plus the procedure itself to put together a team to solve a problem using, possibly, combinations of centralised and distributed scheduling to establish sequences of instance enactment to manage scarce resources such as operating theatre, equipment, etc.
- The agents then representing the staff may, when they make a decision to do something wrt. a patient (an instance of a clinical procedure) their agent would then let other interested/relevant agents/staff that they are doing such and such.
- One possible extension to this is to use ambient sensing techniques to check the enactment of the schedule to provide feedback to the system. This means that it can check that the right people are in the right place at the right time, reschedule or adapt the procedure in case of exceptions, unavailable persons, etc. The advantage is that the system can know where they are, report that they are "on their way", or whatever. However, these systems can tell you where they are, but not what they're doing!
- The location information could give the user a basis for developing a log of what they have been doing.
- Selling the use of agents: their autonomy (and hence their representation) is the most effective means to manage their privacy. It is true that staff may find it (in certain circumstances, such as when they are visiting patients at home) reassuring that the system knows where they are, but the agent can always refuse to inform the system of where you are when, for instance, you're having lunch, but it could pass on a message to you for future reference.
- Broadly speaking you should look at the "business architecture" — the system should reflect the organisational reality.

4.3 Support for clinical research

There was a discussion about the use of data mining techniques to generate anonymised data for NHS research, but unfortunately no notes were taken.

4.4 Pointers

- Marked-up guidelines may provide some of the best content for the Semantic Web.
- Map of Medicine project, UCL. `www.mapofmedicine.co.uk`
- National Electronic Library for Health. `www.nelh.nhs.uk`
- European Commission Directive 356 on E-health.

5 Chronic scenario

The group identified three key issues for this scenario,

(i) the problem of multi-agency intelligence gathering (ii) knowledge coordination (iii) and individual empowerment in health care populations, carers, patients, services

This group interpreted its task as trying to improve society's ability to respond to challenges from chronic health conditions, in terms of the potential for agent technology to mitigate costs, improve provision of care and reduce losses to the economy, community and society as a whole.

5.1 Chronic conditions

- Observation 1: Most people with a chronic illness reject a pharmacological solution to the management of their condition. They are just not taking their prescribed drugs (80% of all prescribed, according to WHO in a report 2004)
- Observation 2: The management of chronic ailments should not be confused with palliative care.
- Observation 3: The purpose of "processing data" to assist in provision of care can be:
  - Acquiring an overall picture of a condition to improve understanding of causal factors (epidemiology)
  - Diagnosing particular conditions (many similar symptoms of very different ailments)
  - Day-to-day maintenance of a good quality of life

In this context we consider a range of chronic conditions:

Kidney disease, diabetes, epilepsy: There is lots of existing work on these conditions. Information can be collected using sensors on and around the body, generating lots of data and hence creating a problem for data-mining, not for agents.

Sexually transmitted diseases: These are notifiable to the public health officer. STDs such as chlamydia and syphilis are long-term problems with life-threatening implications (death, infertility)

Alzheimer's disease: Evidence to date indicates that the longer independent living can be maintained, and hence self-responsibility, the more the progress of the disease can be retarded. However, there is a tension between the aim of independent living and the risks of social isolation, which nowadays is exacerbated both by the fragmentation of families through break-up and increasing geographical dispersion of family members. Approaches were noted that involve the use of sensors in the house and in the wider world to collect information on behalf of the individual and also to monitor the individual.

Depression: This became a major focus of the group's discussion and was eventually turned into a case study. Various properties of the problem were identified:

- Several (governmental) agencies are involved and need to coordinate with one another.
- The ability to provide an acute response is now very limited, since no beds or institutions are available.
- GPs have high workloads and cannot normally give the extended time required to deal with cases of depression
- Depression has a social stigma which means it is a hidden disease that is not discussed that widely, that many people are ignorant of and the causes are under-researched.
- A data point provided is that NHS Direct has been overwhelmed by the length of calls relating to depression. It is a hard decision for the NHS Direct advisor to determine when a medical call has become a mental health call. Likewise it is a delicate matter to decide when intervention by an external agency is required, rather than enabling action by the "expert patient", since a depressed individual cannot reason appropriately for their needs when they are in a low state.

5.2 Issues to address

- How to support "the patient" or "the citizen" in their dealings with agencies for care provision. All agencies have a model of their role and responsibilities and those of other agencies in relation to themselves. The network of support constitutes a *Community of Interest*. A non-exhaustive list of the agencies involved include: the (expert) patient, employer, family, community support networks, public health, general practice, osteopaths, private services, alternative medical services (acupuncture, herbalists, etc.), health visitors and social services, pharmacies, pharmaceutical companies and insurance companies.
- Differences between agencies and organisations: in the use of language and ontology, values and priorities, goals and expression of outcomes.
- Self-diagnosis: using sources such as the Internet, books, friends, non-medical agencies, NHS direct [Protocol generators], general practitioners and consultants.
- When to take action, deciding upon the treatment regime (what interventions when) and the care model.

5.3 A chronic scenario

The group decided to develop and analyse a chronic care scenario, focusing on out-patient depression.

5.3.1 Scenario components

A scenario requires clear identification of the actors and situational factors that drive a series of events, leading to the particular outcomes it describes. Cultural factors must also be taken into account.

Actors: Health system, Community psychiatric nurses / services, GPs, Occupational therapists, Pharmacists, NHS direct.

Last is not connected to patient record unless explicitly done, in various ways. Some areas have satellite-tracked, chauffeur-driven, out-of-hours GPs. NHS Direct tends to exhibit risk-averse behaviour, stemming from call recording.

Formal contacts, outside of the health system include: General social workers, Emergency services (999 call despatcher, Police).

Personal contacts include: Relatives, Friends, Co-habitants, Work colleagues, Professional bodies (e.g. Royal College), NGOs (e.g. MIND, National Schizophrenia Fellowship).

Situational factors: affecting the case are Physical environment, Social / domicile, Time of day.

Ethnicity and culture: Generate a variety of reactions: Attitudes towards the role of GP in community, Attitudes towards litigation and perception of risk, Duty of care towards family members, Frequency of contact, Willingness to divulge information and Language proficiency (speech and literacy).

5.3.2 Scenario narrative

1. Jane is 30. She has been depressed for 15 years but has been managing her condition at home, in the Peabody Trust's Peabody Buildings, Lambeth. She lives with her daughter, 5-year-old Jennifer, and 10-year-old son, Jimmy.
2. Jane has a long medical history and extensive knowledge of her case at her local general practice. Most of this knowledge is recorded in her file but some is known only by individual doctors and nurses at the practice.
3. Jane's daughter, Jennifer, is on the at-risk register after an incident with Jane's ex-partner, and suffers bed-wetting.
4. Jane has been assigned a support worker by social services but the support worker changed three weeks ago. The new support worker was supposed to make his first visit last week but was called away.
5. Jane has not slept significantly for a week and is feeling very tired.

6. At 2am, Jane rings NHS direct on her mobile phone for the 5th night running, complaining about tiredness, aches and inability to cope. [NHS direct logs and records all calls but treats each call as entirely unique].
7. An NHS Direct nurse, Neil, gathers information from Jane. After 25 minutes, he realises Jennifer on the at-risk register and calls over Alice, an at-risk expert.
8. Alice asks for GP name, and the name of Jane's support worker.
9. Jennifer wakes up crying again. Jane rings off.
10. A friend, Fred, phones Jane, to say that Jane's ex, Dan, has just been remanded in custody for drugs dealing again. This means Jane's rent will not be paid this week and, because Dan has been to court for the same offence before, almost certainly faces a custodial sentence this time. Fred is worried.
11. Jane admires Jennifer Lopez as someone who came from a very poor part of New York and made good. Jane has often felt that Lopez is a role model, proving that she can make good too. A radio announcement says that Lopez has been rushed to hospital with an overdose.
12. Jane feels totally abandoned. She phones her incapacitated grandmother, Geraldine, who lives in Brighton. Geraldine feels powerless to help but tries her best to reassure Jane. She is unsuccessful.
13. At 3am, Jimmy, is really annoyed about not being able to sleep because of all the crying. He goes round to his Gran's house, Margery 40, who can tell from Jimmy that Jane is in a very bad way. He tries his best in school but his teacher knows he is rarely in a good enough condition to study.
14. At 3:30am, Jane overdoses.
15. Jennifer can't wake her mum so runs next door to get help.
16. The neighbour Rings 999 and waits for a response. Eventually, Jane is blued into A&E, together with 5 year old Jennifer.
17. A social worker, Sally, takes charge of Jennifer in hospital and finds out about Jimmy. Sally doesn't know that Jimmy is with Margery.
18. Sally informs the police about the missing child. A search ensues.

5.4 Observations

Several risks and indicators were observed with respect to this scenario:

- There is a history of mental health problems and depression
- Patient Contract
- The patient themself demonstrates varying levels of competence, depending on state, while the concept of Expert patient only applies when they are well
- Community care (formal and informal) (NHS Direct calls are all recorded) Delegation of responsibility to social network; no taking of any responsibility

The identified list of agencies / stakeholders in this case is (frighteningly) large (in no particular order):

1. Patient
2. Cohabitants
3. Relatives
4. Friends
5. Religious Confidantes
6. Private Counsellors
7. Health System
8. Community Psychiatric / Mental Health Team
9. GPs
10. Nurses
11. OTs
12. Pharmacists
13. NHSDirect/24 Nurses
14. Social "Services"
15. Social Workers
16. Employer
17. Work Colleagues
18. Educational Institutions
19. Despatcher
20. Police

In addition, the group also identified several national/international level organizations that also ultimately may have a rôle:

1. MIND
2. Pharmaceuticals
3. Insurance Companies
4. NGOs and Charities
5. Royal College of Psychiatrists, and other professional societies

The very size of the list of stakeholder indeed key to the problem, because the information about the patient is very thinly spread across numerous agencies, such that there is never enough in one place to register. The essential property of an agent approach to this problem is that it could gather data from all the stakeholders, effectively sensing the "weak" signals present in individual organizations, and by putting them together, potentially recognise a critical situation and bring it to the attention of those in a position to act.

5.5 The ideal story

Jane has history with GP, history with key worker and has agreed to agent social network trial. This creates opportunities for friends, relatives, and other non-health system people to participate. Patient's agent collects, synthesises, and aggregates these weak signals and is able to trigger support when it is needed. However, it will be virtually impossible to tell when this is successful; only when it fails.

6 Acknowledgements

The organizers thank all the participants for coming to the meeting and contributing so fully. The participants were:

Martin Beer,	Chris Middup,	Simon Thompson
Maged Boulos,	Tim Norman,	Leon Watts
Owen Cliffe,	Julian Padget	
Annabelle Mark	Chris Reed	

The support of the EPSRC is also gratefully acknowledged.